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Catalog No. FB2030
Publication No. 11117

Diffusion and Osmosis

AP* Biology — Big Idea 2, Investigation 4
An Advanced Inquiry Lab

Introduction

How do cell membranes help regulate internal cellular makeup? The purpose of this laboratory activity is to observe, measure, and identify factors that influence diffusion and osmosis in model cells.

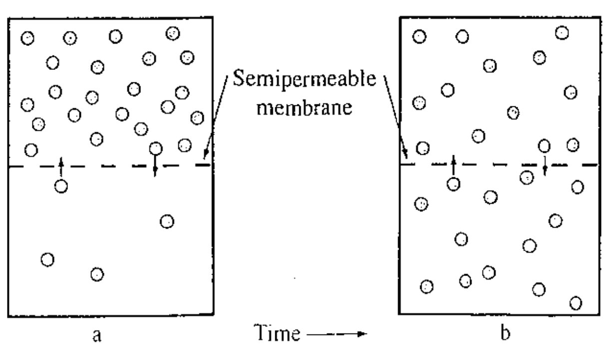
Concepts

- Diffusion
- Cell size
- Concentration gradient
- Hypotonic, hypertonic, and isotonic solutions
- Osmosis
- Surface area/volume ratio
- Semipermeable membrane

Background

A cell must be able to transport materials back and forth across its membrane to maintain homeostasis. This movement is regulated because cell membranes are selectively permeable. *Selective permeability* means that some substances can pass through the membrane while others cannot. Both solutes and solvents may cross the cell membrane.

Diffusion is the movement of solute from an area of higher concentration to an area of lower concentration. The mechanism of diffusion is quite simple. Molecules and ions are in constant motion. Since they are always moving they will eventually collide with one another. The higher the concentration of molecules, the greater the number of collisions (see Figure 1a). These collisions cause the molecules to change direction and to spread out until they eventually become uniformly distributed (See Figure 1b). Even after the molecules are evenly distributed, they are still moving, causing them to collide and redistribute. Molecular motion does not cease when uniform distribution is reached. Consequently, uniform distribution is called a *dynamic equilibrium* because there is no further net movement of the molecules down a concentration gradient. The term concentration gradient simply describes a difference in concentration across a physical distance. Diffusion is one of the key processes involved in the movement of materials into and out of cells and throughout living systems.



Diffusion across a Membrane

Figure 1.

Water travels through membranes by a diffusion process known as osmosis. *Osmosis* is the diffusion of water through a selectively permeable membrane from an area where it is more concentrated to an area where it is less concentrated. The terms hypotonic, hypertonic, and isotonic are used to describe the relative concentrations of different solutions. A *hypotonic* solution has a higher concentration of water and a lower solute concentration than a reference solution, while a *hypertonic* solution contains a

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5. Review the possible solutions listed for Part 2 in the *Materials* section. a) Using those materials, select four different pairs of solutions, including water, to study in the *Baseline Activity*. One solution of each pair will go inside a model cell, and the other solution will be placed in the surrounding environment. Enter your choices in Table 2. b) What is the purpose of Trial No. 5, with water in both compartments?

Table 2.

No.	Model Cell (inside dialysis tubing)	Surrounding Environment (plastic cup)	Net Diffusion (into or out of cell)
1			
2			
3			
4			
5	Water	Water	

6. Using your knowledge of concentration gradients and the permeability of the membrane, predict whether there will be net diffusion of water by osmosis into or out of each model cell. Enter your prediction in the table.

Materials*

Part 1. The Rate of Diffusion and Cell Size

Hydrochloric acid, HCl, 0.1 M, 150 mL

Phenolphthalein agar block

Sodium hydroxide, NaOH, 0.1 M

Beaker, 150-mL

Metric ruler

Paper towel

Plastic knife

Plastic spoon

Part 2. Modeling Osmosis and Diffusion

- Albumin, 5% solution
- Glucose solution, $C_6H_{12}O_6$, 1 M
- Sodium chloride solution, NaCl, 1 M
- Sucrose solution, $C_{12}H_{22}O_{11}$, 1 M
- Water, distilled or deionized

possible Solutions

Balance, 0.01-g precision

Cups, plastic, 9-oz

Dialysis tubing, 18 cm

Funnel

Graduated cylinder, 25-mL

Permanent marker

Weighing dish, large

**Amounts will vary based on the experimental design for the guided-inquiry experiments.*

Safety Precautions

Hydrochloric acid is toxic by ingestion and inhalation. Sodium hydroxide and hydrochloric acid solutions are corrosive to skin and eyes. Phenolphthalein solution contains alcohol and is a flammable liquid. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Follow all normal laboratory safety guidelines and wash hands thoroughly with soap and water before leaving the laboratory.

7. Twist and knot the open end of the tubing to seal the bag of dialysis tubing.
8. Gently rinse the dialysis tube bag with DI water to make sure none of the solution within the bag has dripped on the outside. *Note:* This step may be omitted if the bag contains DI water.
9. Place the dialysis tube bag on a paper towel and gently roll it back and forth to remove any excess liquid.
10. Place a weighing dish on the balance and zero the balance.
11. Measure and record the mass of the dialysis tube.
12. Fill cup number one with approximately 100 mL of the solution listed in the Surrounding Environment column, row 1 of Table 2.
13. Place the dialysis tube bag in cup 1.
14. After 30 minutes remove the dialysis tube bag from the cup. Gently roll it back and forth on a paper towel to remove excess liquid. Measure and record the final mass of the dialysis tube bag.
15. Repeat steps 3–14 with the remaining solutions chosen in Table 2.

Analysis of Results

Calculate the percent change in mass for each model cell and explain the results in terms of membrane permeability, the nature of the solutes, and solution concentration. Identify the solutions as hypotonic, hypertonic or isotonic. Discuss whether any of the experiments provide evidence for the permeability of the membrane with respect to specific solutes.

$$\text{Percent change} = \frac{(\text{Final mass} - \text{Initial Mass})}{\text{Initial mass}} \times 100\%$$

Guided Inquiry

1. Living cell membranes are selectively permeable and contain protein channels that permit the passage of water and various molecules. Dialysis tubing is similar to a cell membrane in many ways. Consider the following questions while reflecting upon your knowledge of membrane permeability, osmosis, and diffusion.
   a. Is the rate of diffusion directly proportional to the solute concentration?
   b. What other variables might influence the rate and direction of osmosis?
   c. How would diffusion of a starch solution be different than that of a protein?
   d. How could you prove or disprove that a specific solute, such as sucrose, was able to diffuse through a semipermeable membrane?
2. Design a controlled experiment to answer one of these questions or investigate a variable that might affect the exchange of nutrients between a model dialysis cell and its surrounding environment.
3. List any potential physical or chemical hazards that may arise in the experiment and identify the safety precautions that must be followed to reduce these hazards.
4. Review your hypothesis, safety precautions, procedure, data table and proposed analysis with your instructor prior to doing the experiment.
5. Analyze the results and explain how you might use a procedure such as this to determine the solute concentration inside a living cell.